Logistics Management Institute

American Youth, Science, and Engineering in the New Century

IR517LN1

Dayton S. Pickett
David A. Smith

LMI

October 1996

American Youth, Science, and Engineering in the New Century

IR517LN1

Dayton S. Pickett
David A. Smith

Logistics Management Institute
2000 Corporate Ridge
McLean, Virginia 22102-7805

Contents

TABLES

Preface

Can America's youth meet the needs of science (including mathematical science) and engineering—or SME—that will arise in the new century? We are concerned over a number of gloomy articles and speeches and propose to set the record straight by recounting relevant history since World War II, describing the SME pipeline that supplies professionals for these fields, and discussing supply-and-demand factors that bear on the issue. We attack the notion that American youth are becoming less able academically, while pointing out that lower numbers of college-bound youth are now choosing to pursue SME majors and careers. When all factors are considered, a shortage of SMEs in the 21st century is possible. The problem, we believe, is motivation, not ability. Four options for meeting the challenge are presented, accompanied by a discussion of the advantages and disadvantages of each.

American Youth, Science, and Engineering in the New Century

A Roller Coaster Relationship

The relationship of the American people with our youth's prowess in mathematics, science, and engineering has often brought out the emotions we feel about our own children as they grow and develop. We have at some times bragged proudly about accomplishments and at others have become concerned, then worried, as we read reports about falling standardized test scores and articles on the "dumbing of America." Our collective concern reached a peak of sorts in 1992 when President Bush announced a series of national goals for what has become known as Education 2000, a brief, ambitious list of objectives intended to heighten interest and improve performance in (among other things) the education of America's scientists—including mathematical scientists—and engineers.

With much rhetoric, occasional enlightenment, and no little "hype" on this subject in the popular press, it is difficult to discern the true condition of our national abilities and the outlook for the future in these fields. Should we be worried? Are our youth simply unable to compete intellectually and academically with their contemporaries abroad? Will the growing tide of international graduate students entering our universities and approaching our laboratories and research centers continue?

In a simplified way, this report is intended to set the record straight. The authors have been interested observers of this scene for the past decade. During that period, they have performed a succession of projects for the Defense Department, which is always attuned to the supply of and demand for high-quality scientists, mathematicians, and engineers (inevitably labeled "SMEs" in Defense shorthand) available to work on national defense issues. While engaging in those projects, they have been able to study the trends that underlie the present state of the education of the American young people who become our scientists, mathematicians, and engineers—our future SMEs.

The Historical Perspective

It will aid understanding if we approach our present condition in the light of history since World War II.[1] America emerged from that conflict with high public

[1] Many of the specifics in this review are taken from Richard C. Atkinson's president's lecture at the American Association for the Advancement of Science (AAAS) annual meeting in New Orleans on 18 February 1990.

confidence in our world-class scientific abilities and accomplishments. We had split the atom, penetrated and cracked Japanese codes, and developed and used the mass-production techniques that eventually helped overwhelm formidable enemies at opposite ends of the world. Furthermore, by late in the war we were embarking on a new relationship between our government and basic research and science education throughout the country. As a result of the foundational work of Vannevar Bush and others, federal aid to research and education was becoming a reality.

With the creation of the National Science Foundation (NSF) in 1951, the vehicle for moving federal funds to universities and other worthy recipients was in place. For over a decade following the war, the American people were comforted by these and other triumphs as hundreds of thousands of veterans returned to school under the GI Bill of Rights, swelling college populations to historic levels. In our own eyes, America had become, after all, the best-educated and most able nation on earth.

In 1957 the bubble burst. With the successful launch of the earth satellite Sputnik, the Soviet Union—with which the United States was in serious competition internationally—displayed a technological edge that shook America's confidence. Articles in the press, discussions on Main Street, and debate in the Congress all addressed the same questions: What had gone wrong? Weren't we the best after all? How could we regain our lost leadership? Two things seemed certain: we needed to increase the rigor of our academic education, and we certainly needed to channel more of our best and brightest into SME studies. As an aid in attracting bright young people to SME studies and careers, a number of governmental and private educational aid programs were established. NSF appropriations more than tripled. And large numbers of America's youth responded. That reaction was very much in tune with the patriotism of the early 1960s. In addition, of course, attractive financial incentives made SME studies more appealing.

Simultaneously, however, a series of developments were beginning that were to have profound effects on the ambitions, goals, priorities, and academic choices of the nation's students.

First, the digital computer was beginning to come of age both as a research tool and as the focus of a new academic discipline. Computer science proved so attractive that in 1986, the year in which its popularity peaked, 42,000 graduates received bachelor's degrees in that discipline in the United States.[2] Other new or relatively new disciplines bade for the attention of the most able students. Journalism, while relatively well established by the 1960s, was moving toward investigative journalism, with its cops-and-robbers excitement. Meanwhile, interest in space technology continued to grow. By the end of the decade, with America's

[2]Thomas D. Snyder, Project Director, *Digest of Education Statistics — 1995*, Washington, D.C.: U.S. Department of Education, National Center for Education Statistics (NCES 95–029), October 1995, p. 297.

successful Apollo 11 mission to the moon accomplished, we were once again the proud "parents" of overachieving SME men and women who were international heroes. America's interest—as reflected by the study choices of its sons and daughters in college—held SME studies and careers in high regard. But that would not be true for much longer.

The foundations had begun to crumble. We were experiencing a spreading disaffection with national leadership and a suspicion of authority that had started in earnest over the conduct of the Vietnam War in the mid-1960s. Rejection by students was but a part of a wider and deeper suspicion and cynicism about a number of pillars of earlier respect and admiration. Science and mathematics, once objects of such regard, were losing favor because they were amoral, difficult, and uninteresting. Hadn't science brought the threat of worldwide nuclear war upon us? Wasn't war evil, as evidenced by the atrocities of Vietnam? Hadn't our leaders been lying to us about much of what is good, pure, and worthy? Saving the earth, not destroying it, seemed much the better way. The study of biology and the other life sciences was becoming more popular, led by the relatively new discipline of ecology. These academic majors represented areas of genuine appeal to students seeking worthy goals in life.

By 1985 student interest in SME studies had reached its apex and was beginning to slip away. The drop in enrollments was precipitous in some fields. By 1989, amid widespread observations of pessimism and gloom, the National Science Foundation projected an SME deficit of 675,000 professionals by the year 2000.[3] While this NSF report has since been largely discredited as having been based on faulty methodology, its appearance was but one more voice of dread heard across the national SME landscape. National test scores were dropping, and comparisons with youth of other countries were not encouraging. Fewer students were choosing tough courses. It was time for action. Waiting would only compound the problem.

At a special conference of the nation's governors in Charlottesville, Virginia, in 1992, President Bush set forth for the first time the new National Education Goals. Now, almost 5 years later, the nation's leaders and many educators and observers continue to worry about the future of formal learning in America, and many of us in the general public have incorporated those concerns into our own vision of America as well. Just how accurate is this pessimistic vision of our nation's SME future? Where are we headed?

Our Objective

This report seeks to establish several important points:

- American youth are more able than many people think.

[3]National Science Foundation, Division of Policy Research and Analysis, *Future Scarcities of Scientists and Engineers: Problems and Solutions*, working draft, 25 April 1989.

- Our brightest students are growing in number and in ability.
- Surprising—and growing—numbers of people in this country are attending college each year.
- More and more students are so positioning themselves that they could pursue SME studies and careers.
- There are truly promising signs of achievement and ability among minority and female students.
- However, there still seems to be a persistent national malaise, or an aversion to college-level SME studies and careers on the part of American youth.
- *The principal problem, therefore, is not one of ability and intelligence. It is one of motivation and direction.*

The final section of this report sets forth four alternative approaches to the problem and examines the advantages and disadvantages of each. First, however, it is important to review the process by which men and women become SMEs.

THE SCIENCE, MATHEMATICS, AND ENGINEERING PIPELINE

One may think of the SME "pipeline" as both a "system" and a group of individuals. The system is that portion of the formal education system through which students pass on their way to careers in science, mathematics, or engineering. The pipeline contains within its bounds all of the students able, equipped, and motivated to pursue SME careers.

The pipeline is more or less continuous throughout the educational process, although its composition differs at various stages. In the early grades of elementary school, the pipeline includes many children who have not yet focused on specific curricular choices. Later, in secondary school, differences become evident as the curricular choices and career plans of the students become more specific. During this time, some students complete academic courses with sufficient rigor to equip them adequately to move toward more advanced SME curricula if they so choose. The differentiation process continues throughout college, as students narrow their degree objectives and career plans. Those remaining in the SME pipeline commit to pursuing SME bachelor's, master's, and even doctoral programs as they work their way toward the beginning of their careers.

Thus the pipeline narrows progressively throughout its length as a result of a series of attrition and selection processes. Losses occur for several reasons: some

able students are simply not attracted to SME studies, others are not academically capable, while still others demonstrate adequate ability but are unwilling to attack the more demanding mathematics, engineering, and science curricula.

A careful examination of the SME pipeline, however, shows that it is characterized by a significant amount of elasticity, as well as by migration into and out of it:

> . . . the pipeline is not filled solely by the determined core of committed students who display early promise, high achievement, and drive. Estimates suggest that one-quarter of those who eventually go on to major in science and engineering come from outside the academic (college-preparatory) curriculum track.[4]

These dynamics are further quantified:

- At the high-school sophomore point, as many as 33 percent of those in the pipeline come from nonscience and nonengineering curricula.
- By the time students are high-school seniors, up to 26 percent have left the pipeline.
- At the start of college, up to 19 percent of the students in the pipeline have come back into the pipeline after dropping out earlier.
- During college, up to 27 percent of the pipeline is made up of students coming in from nonscience and nonengineering curricula.[5]
- The products of this pipeline keep adding to the total SME population—the group that has been the subject of so much concern in recent years. In order to provide an adequate number of new SMEs to augment the already existing supply, the pipeline must hold sufficient numbers of academically capable students to ensure that enough degreed SME professionals are produced each year. The next question is, how much is enough?

Supply and Demand

Historically, the population of SME professionals, especially engineers, has been volatile. Since World War II, we have seen three general cycles of shortage followed by abundance. These have followed economic expansions and recessions, defense buildups and cutbacks, space program growth and retrenchment, and the

[4]Daryl E. Chubin, Project Director, *Educating Scientists and Engineers: Grade School to Graduate School*, Washington, D.C.: U.S. Congress, Office of Technology Assessment, June 1988, p. 13.

[5]Daryl E. Chubin, Project Director, *Elementary and Secondary Education for Science and Engineering—A Technical Memorandum*, Washington, D.C.: U.S. Congress, Office of Technology Assessment, December 1988, pp. 10–12.

like. Shortages have been followed by oversupply and back to shortage, especially in certain disciplines and specialties. The one lesson learned from examining these cycles is that it is hazardous to make predictions about the future supply and demand of SMEs. The growth of these resources has been uneven, uncertain, and often dependent upon unpredictable events.[6] Significant shortages predicted in the late 1980s did not materialize, as a result of the recession of 1990 and the accompanying reduction in defense expenditures, which curtailed the demand more than the supply, which itself was reduced by lower graduation rates of degreed SMEs.[7]

Forecasting SME supply and demand involves extrapolating, correlating economic and enrollment variables, analyzing immigration, applying mortality rates, predicting transfers in and out of the professions, and determining changes in retirement policies. Economics plays an important role on both sides of the equation of supply and demand. The concept of a free market holds that there is always an increased supply available at a higher market price and a smaller supply at a lower market price.[8] In actual practice, however, the SME labor market responds to changes in salaries only after a lag of 4 or 5 years. Growth in salaries results eventually in increasing degree awards in SME.[9] While the forces acting on SME supply and demand do create periodic highs and lows on both sides, an increase in demand ultimately produces an increased supply.

At best, we can say that over the long haul, we should expect to see both supply and demand grow at average rates, which the U.S. Department of Labor describes as approximating the levels existing in the late 1980s. This would result in growth of about 20 percent in SMEs from 1990 through 2005, which would be about the same rate as the one at which the economy is expected to grow as a whole.[10]

Although we might not be able to predict accurately the actual supply of and demand for SMEs into the next century, we can be sure that there will be a demand at some level, and that whatever it turns out to be, we will need academically capable students in the SME pipeline to meet it. The following subsections discuss the SME pipeline in greater detail and examine its subsets and composition.

---

[6]Richard C. Atkinson, "Supply and Demand for Scientists and Engineers: A National Crisis in the Making," *Science*, Vol. 4, 27 April 1990, p. 424.

[7]*Ibid.*, pp. 425–432.

[8]Robert A. Rivers, "Forecasting Engineering Supply and Demand," unpublished paper for Institute of Electrical and Electronics Engineers–USA Manpower Committee, undated.

[9]Michael G. Finn and Joe G. Baker, "Future Jobs in Natural Science and Engineering: Shortage or Surplus?" *Monthly Labor Review*, Washington, D.C.: U.S. Department of Labor, February 1993, pp. 54–58.

[10]Douglas J. Braddock, "Scientific and Technical Employment—1990–2005," *Monthly Labor Review*, Washington, D.C.: U.S. Department of Labor, February 1992, pp. 28–41.

Pipeline Composition

For the purpose of analysis and discussion, we can identify three population subsets or pools within the SME pipeline. Although they are not well defined and overlap somewhat, they provide a useful insight into the composition of the overall SME pipeline population:

- *The talent pool.* Those students who have the intellectual ability to go on to SME careers if they choose to make the commitment and accomplish the work.
- *The academically able pool.* Those students who have satisfactorily completed a curriculum with enough academic rigor to be considered "on track" for future SME curricula. All they need to do is to continue on this track.
- *The committed pool.* Those students who have decided to pursue SME careers. This group has some elasticity, as discussed above, with students moving into and out of it at various stages of their career development.

We will next look at each of these pools in turn and discuss some of their characteristics.

THE TALENT POOL

School children in the talent pool have the *intellectual ability* to go on to SME careers if they should so choose. In other words, these students have the necessary innate intelligence and basic mathematics and science literacy to permit them to prepare themselves to major in one of the SME disciplines if they wish to do so.

An assessment of this intellectual ability is made periodically by the U.S. Department of Education using standardized tests of selected students in various subjects and disciplines. This process is accomplished through the "National Assessment of Educational Progress" tests, and the results are published by the National Center for Educational Statistics. Table 1 reflects selected test scores in mathematics and science for 9-, 13-, and 17-year-old students in 1982 and, in comparison, again in 1992.

For all groups considered, and for all students collectively, average test scores in both mathematics and science increased between 1982 and 1992. Some of these improvements were significant.

Table 1. Average Mathematics and Science Test Scores

Group by subject	9-year-olds		13-year-olds		17-year-olds	
	1982	1992	1982	1992	1982	1992
Mathematics						
Male	217.1	230.8	269.2	274.1	301.5	308.9
Female	220.8	228.4	268.0	272.0	295.6	304.5
White	224.0	235.1	274.4	278.9	303.7	311.9
Black	194.9	208.0	240.4	250.2	271.8	285.9
Hispanic	204.0	211.9	252.4	259.3	276.7	292.2
All students	219.0	229.6	268.6	273.1	298.5	306.7
Science						
Male	221.0	234.7	255.6	260.1	291.9	299.1
Female	220.7	226.7	245.0	256.0	275.2	289.0
White	229.0	239.1	257.3	267.1	293.1	304.2
Black	187.0	200.3	217.1	224.4	234.7	256.2
Hispanic	189.0	204.7	225.5	237.5	248.7	270.2
All students	220.8	230.6	250.1	258.0	283.3	294.1

Source: National Assessment of Educational Progress (NAEP) test scores from Thomas D. Snyder, Project Director, Digest of Education Statistics—1995, Washington, D.C.: U.S. Department of Education, National Center for Education Statistics (NCES 95-029), October 1995, pp. 121 and 127.

THE ACADEMICALLY ABLE POOL

The academically able pool includes those students from the talent pool who have satisfactorily completed a curriculum with enough *academic rigor* to be considered "on track" to complete future SME curricula satisfactorily.

The improvements shown in the talent pool, discussed above, may be the result of the movement, started in the 1980s, to require more high-school graduation credits (Carnegie units), including increased numbers of credits in mathematics and science. Table 2 reflects the growth in the numbers of high-school graduates earning the increased credits, also referred to by some as "new basics" requirements.

Table 2. Change in Numbers of High-School Graduates Earning Minimum Carnegie Units in Selected Academic Courses

Year	Number of high-school graduates	Percentage taking new basics	Number taking new basics
1982	2,995,000	13.4	401,000
1987	2,694,000	28.6	770,000
1990	2,588,000	39.9	1,033,000
1992	2,482,000	46.8	1,162,000
Difference 1982–1992	(513,000)	33.4	761,000

Source: Snyder (NCES 95-029), pp. 108 and 134.

Note: Minimum Carnegie units = 4 units of English, 3 of social studies, 3 of science, and 3 of mathematics.

These data are significant. Despite a decline in the number of high-school graduates of over a half million between 1982 and 1992, the number of students graduating and having completed a more rigorous curriculum of science and mathematics rose by over three-quarters of a million. The number of youth now academically able to pursue SME degrees and careers is increasing significantly.

In addition to the increase in the numbers of high-school students taking more rigorous courses on the way to graduation, we see similar positive trends in the scores achieved in the Scholastic Aptitude Test. Although average test scores have been only marginally higher in recent years, the numbers of students excelling in the tests (scoring 600 or above on the math SAT) are up significantly. This is reflected in Table 3.

Table 3. Number of High-Scoring Students on the Math SAT

Year	Number taking the SAT	SAT math score of 600 or more
1980	991,056	149,615
1985	977,361	166,932
1990	1,025,523	188,812
1995	1,067,993	229,713
Change 1980–1995	76,937	80,098
Percentage change 1980–1995	7.76	53.5

Source: *National Report on College Bound Seniors—Profile of SAT and Achievement Test Takers*, New York: The College Board, 1980–1995.

Note: SAT scores reported above have not been recentered. Recentering will commence with the class of 1996.

Even though the college-age youth cohort is down, the number of students scoring 600 or above on the math SAT has gone up significantly. The increase of over 80,000 students scoring 600 or above represents an increase of 53.5 percent in a 15-year period during which the number of test takers went up by only 7.76 percent. In addition, Donald M. Stewart, President of the College Board, reported on 24 August 1995, that average SAT scores for the high-school graduating class of 1995 had increased 3 percentage points for math and 5 points for verbal. Mr. Stewart attributes these increases to "... recent improvements in academic preparation."[11]

We have established, then, that large numbers of academically able youth are coming out of our high schools. The problem is to encourage enough of them to enter SME college and university programs to meet the needs of the country, whatever they turn out to be. The next subsection discusses this issue.

THE COMMITTED POOL

The committed pool is a subset of the academically able pool comprising those students who *intend to pursue SME careers*. Insight into how many college students intend to follow such careers can be gained by examining freshman interest in science and engineering. The University of California, Los Angeles, through the Cooperative Institutional Research Program, conducts an annual survey of freshman college students examining characteristics of over 8 million students at 1,300 institutions. A part of this study assesses freshman interest over the years in pursuing careers in science and engineering. Starting in 1966 and running through the mid-1980s, the surveys showed that

- interest in fundamental undergraduate science majors among college freshmen dropped dramatically,
- interest in technology careers also declined, and
- more than half of the students who entered college planning to pursue science majors changed to nonscience fields.[12]

This drop in SME career interest, when coupled with the reduction in the size of the college-age population, has led to significant concern about future SME bachelor's degree production.

Continuing the trends, by 1995, SME career interest had fallen to a point lower than in 1980 in nearly all SME disciplines, with the notable exception of the biological sciences (see Table 4).

[11] "News from The College Board," New York: The College Board, 24 August 1995.

[12] *The American Freshman: National Norms*, Cooperative Institutional Research Program, Los Angeles: University of California.

Table 4. Freshman Interest in SME Programs
(as a percentage of total first-time, full-time enrollment)

Major	1980	1985	1990	1995
Physical sciences	2.0	1.6	1.7	1.7
Biological sciences	3.7	3.4	3.7	6.9
Mathematics	0.6	0.7	0.7	0.6
Engineering	11.8	10.7	9.6	7.4
Computer science	4.0	6.1	2.6	3.2
First-time, full-time freshman enrollment	2,588,000	2,292,000	2,257,000	2,150,000
Total percentage	23.4	20.8	18.3	19.2
Number of freshmen interested	606,000	477,000	413,000	413,000

Source: Cooperative Institutional Research Program, The American Freshman: National Norms for 1980, 1985, 1990, and 1995, Los Angeles: University of California.

Note: Number of freshmen interested is computed by multiplying total freshmen enrolled by the percentage interested.

These data are not reassuring. Over 30 percent fewer college and university students now indicate interest in pursuing SME programs than they did in 1980. In addition, only the biological sciences show improvement (and it is significant) in comparison with 1980, while computer science, the physical sciences, and—especially—engineering declined from their 1980 levels. The number of college freshman intending to study SME was the same in both 1990 and 1995. In general, interest in SME shows little overall improvement in percentage terms while, at the same time, the college-age cohort is significantly smaller than it was in 1980. The challenge for the future is to find a way to increase college students' interest in SME programs sufficiently to ensure that graduates will be coming out of the SME pipeline when we need them.

In the next sections, we look at the demographic realities, at who are the students currently enrolled in SME programs in colleges and universities, and at who are those completing bachelor's degrees in SME programs.

Demographic Considerations

Between 1980 and 1995, the college-age youth cohort (18-year-olds) decreased by nearly 20 percent, as reflected in Table 5.

Table 5. U.S. Population of 18-Year-Olds (in millions)

Category	1980	1995	2005	2010
White	3.5	2.7	3.2	3.5
Male	1.8	1.4	1.6	1.8
Black	0.6	0.5	0.6	0.7
Hispanic	0.3	0.4	0.6	0.8
All 18-year-olds	4.2	3.4	4.1	4.5

Sources: 1980: Louisa Miller, *Population Projections of the United States, by Age, Sex, and Race: 1980–1982*, U.S. Bureau of the Census (Series P-25, No. 929), November 1993. 1995–2010: Jennifer Cheesman Day, *Population Projections of the United States, by Age, Sex, and Race, and Hispanic Origin: 1993–2050*, U.S. Bureau of the Census (Series P-25, No. 1104), November 1993.

Note: 1995 estimated; 2005 and 2010 projected.

It will take until after 2005 for the population of 18-year-olds to reach the previous peak, seen in 1980. By that time, the composition of this population will be significantly different. The percentage of nonwhite youth in 1980 was 17 percent, while in 2010 it will increase to 22 percent. At the same time, the white male population will decrease from 43 percent to 40 percent. Because of these trends, some observers believe it essential that more women and minorities be attracted to SME careers in order to provide a sufficient supply in the future.[13]

Looking a little farther along in the pipeline, college and university populations also show significant changes (see Table 6).

Table 6. Enrollments in U.S. Institutions of Higher Education (in millions)

Category	1980	1995	2005
Male	5.9	6.7	7.3
Female	6.2	8.5	8.8
14–17-year-olds	0.3	0.3	0.3
18–24-year-olds	7.3	8.2	9.3
25–34-year-olds	3.1	3.6	3.3
35-year-olds and over	1.4	3.1	3.2
Undergraduate	10.5	13.1	14.0
Graduate	1.3	1.8	1.8
First professional	0.3	0.3	0.3

Source: Debra E. Gerald et al., *Projections of Education Statistics to 2005 (NCES 95-169)*, Washington, D.C.: U.S. Department of Education, January 1995, pp. 26, 29, 37, 40, and 43.

Note: 1995 estimated; 2005 projected.

[13]Atkinson, p. 431.

At some point between 1975 and 1980, the number of female enrollees at colleges and universities for the first time exceeded the number of male enrollees. That trend continues. However, the number of male enrollees also continues to grow instead of decreasing or even just leveling off, as was previously feared. Also, there is a large percentage increase in older people enrolling in colleges and universities. Focusing on the prime student group—people 18 to 24 years old—it can be seen that this group also expanded in the 1980–1995 period and that it is projected to continue to do so into the 21st century. As a result of these trends, overall undergraduate enrollment shows strong growth.

These data show that the participation of U.S. youth in higher education continued to rise between 1980 and 1995 even in the face of the significant decline in the 18-year-old cohort illustrated in Table 5. More males and females, more 18- to 24-year-olds, more people enrolling for undergraduate degrees—all of these increases show that the overall pool of students pursuing higher education continues to grow. Because enrollment projections are not made for racial and ethnic groups, it is not known how demographic changes in those groups will change the historical mix of students actually pursuing higher education.

Finally, a look at bachelor's degrees conferred provides further insight into the SME pipeline (see Table 7).

Table 7. U.S. Bachelor's Degrees Conferred (in thousands)

Category	1980	1985	1990	1993
All bachelor's degrees				
Male	474	483	492	531
Female	456	497	560	629
All bachelor's degrees	929	979	1,051	1,160
SME bachelor's degrees				
White	137	172	138	137
Black	7	9	9	11
Hispanic	3	5	6	7
Asian/Pacific	5	11	14	17
Male	120	153	127	127
Female	40	59	50	55
Foreign students	8	12	10	10
All SME bachelor's degrees	160	212	177	182

Source: Snyder (NCES 95-029), pp. 250 and 284.

Note: 1993 is estimated. Numbers may not add to totals due to rounding.

The total number of bachelor's degrees awarded has continued to increase, in step with enrollments and in contrast to the decrease in the numbers of college-age youth. However, as shown, the numbers of SME bachelor's degrees awarded to whites and to men and the overall number of SME degrees awarded peaked in 1985 and have now fallen to relatively close to 1980 levels. The number of minority students awarded SME degrees continued to rise over the entire 1980–1993 period.

ASSESSMENT

The data are both encouraging and discouraging. On the positive side, more and more high-school students—in terms of both percentages and absolute numbers—are taking the foundation courses that would enable them to pursue SME degree programs in colleges and universities. On the negative side, in comparison with 1980, a smaller percentage of college and university freshmen are expressing interest in enrolling in SME degree programs, and the absolute number is down by nearly 200,000. The problem is compounded by the fact that the numbers of first-time, full-time freshmen have fallen about 17 percent, a figure consistent with the decrease in the college-age cohort between 1980 and 1995. These factors, in combination, could cause a shortage of degreed SMEs as we enter the 21st century.

While the numbers of college-age youth are projected to start increasing again, the composition of this cohort is going to be significantly different—with more minorities and a smaller percentage of white male youth.

The issue, therefore, is how to increase the overall interest of students in studying SME disciplines as well as ensuring that more minorities and women prepare themselves to enter the SME pipeline.

CONCLUSIONS

We have seen that there are large numbers of youth in the SME pipeline who are intellectually able and academically capable of pursuing careers in SME disciplines. This group still includes large numbers of white males, the principal source of SME careerists in the past. In addition, significantly higher numbers of female and minority students are preparing themselves for these fields; many are committing themselves to SME careers, although from a much smaller base.

We have also seen that it is exceedingly difficult to make confident predictions regarding the future supply of and demand for SME professionals. The dynamic factors affecting this supply and demand—uncertain cycles, long lead-times, and periods of over- and under supply—are the principal causes of uncertainty. There is good evidence that supply actually does respond to demand and does tend to approach demand levels through the operation of normal market forces. A major difficulty of this particular market is a 4- to 5-year lag time between the perceived

increased demand and the resulting change in supply—especially for those SME professionals arriving on the scene from academic institutions, as opposed to those who reenter the SME work force from other endeavors.

In view of all these phenomena, should more youth now be entering SME career programs in colleges and universities? If so, how many more? How can they be motivated to choose SME curricula and careers?

More youth should be encouraged to enter SME programs. Why?

- The information explosion now occurring threatens to swamp the teaching–learning process. A growing percentage of the information is technical, and much of it is technological. The future will require marked increases in the public's technological literacy and ability to communicate in that idiom. Only people with technological education's can provide the necessary growth in understanding that will be needed to meet this challenge.

- The technological revolution is intensifying, expanding, and spreading into most aspects of life. While many of technology's applications appear simple, the process of moving from theory to usable outcome is fraught with growing—and increasingly complex—engineering challenges. We are not now equipped to meet those challenges.

- The United States is not producing SME graduates at rates nearly comparable with those of the recent past. In the 8 years between 1985 and 1993, the percentage of bachelor's degrees awarded in SME, considered as a subset of all bachelor's degrees awarded annually, fell from 21.7 percent to 15.7 percent. In numbers of graduates, that meant a real decline of 30,000 SME graduates (from 212,000 to 182,000) at a time when all bachelor's degrees awarded rose by over 18 percent, or by 181,000 graduates. Even if our 1985 SME production rates were higher than necessary to meet the nation's needs (an allegation no one has made), this decline is surely precipitous in terms of production.

- Overall, fewer and fewer students entering college see their futures in SME careers. With the long lead-time of these disciplines, this shrinking interest means that the present worrisome situation will only worsen with time, short of some redirection of college freshman interest. The situation becomes of even greater concern when one looks beneath the surface. With the notable exception of the biological sciences, freshman interest in virtually every SME field has fallen off since 1980 (mathematics has remained level). The decline in interest in engineering has been particularly significant.

- To remain a superpower in the 21st century, the United States absolutely must be competitive in the international marketplace. To do that effectively, we need world-class scientists and engineers. If our academic SME pool, from which we draw these superstars, is limited in size and ability, our future ability to compete is called into question.

We believe it is in the best interest of the United States and its citizens that more American youth be encouraged to pursue studies and careers in SME disciplines. From a public policy perspective, four main options might be considered that would address this issue. These are discussed in the next section, with advantages and disadvantages summarized for each option.

OPTIONS

Option 1. *Do nothing. Let the marketplace establish demand, and let the supply catch up—even with lag time—as a result of economics and market forces.*

If nothing else is done, of course, this is the option that we will live with. It calls for less government involvement and smaller expenditures, in line with the trends of the time.

Advantages. With periodic exceptions, the classic laws of supply and demand have operated to govern the SME market. In the long range, this option will always work, although with some unavoidable lag time as supply and demand each change over time.

Disadvantages. The main disadvantage of this option is that, at least in the short run, it is very inefficient and unresponsive. The 4- to 5-year lag time creates cycles of supply and demand that are out of phase with each other. This discontinuity has at some times produced stories of graduate engineers driving taxicabs and, at others, has resulted in shortages in important specialties. We see here a real waste in terms of human costs, as well as serious losses for those institutions and organizations requiring properly educated SME personnel. This option is not efficient, and its results may be too little and too late. It may not be in our national interest to treat this issue in such a laissez-faire manner.

Option 2. *Establish new and increased public incentives for students to pursue SME academic programs and careers.*

At various times since World War II—such as after Sputnik—the Congress has appropriated funds and initiated special programs to encourage more students to select SME for college and university studies and careers. These incentives have taken the form of federal grants, scholarships, fellowships, research contracts, and the like.

Advantages. Such an effort would represent a truly national action to meet a perceived national need. It would be proactive rather than reactive. While difficult to administer with proper sensitivity, this option, if adopted, will work.

Disadvantages. Considering the new realities in the nation's politics, with decreasing federal involvement in many areas, a balanced budget, and a smaller federal government, this option may be impossible to implement. It smacks of an "uncle-knows-best" approach that is now in disfavor. The public may not be willing to support a program of this kind in the foreseeable future.

Option 3. *Identify ways to reduce loss from the SME pipeline of youth who have made an initial commitment to SME curricula and careers but who for various reasons leave the pipeline.*

It is clear that the SME pipeline gets steadily smaller as time goes by and that the students grow older. The first major reduction occurs in the early years of secondary school, when the opportunity arises for some students to actually begin more rigorous course sequences in science and math. The next major narrowing of the pipeline occurs during the time between high school and college. For a wide variety of reasons, large numbers of well-prepared, talented students forego collegiate study. Between the beginning of the college freshman year and the end of the sophomore year, the pipeline undergoes additional, significant shrinkage. Once students successfully get into junior-year studies, however, the attrition slows. Then, upon graduation, a number of pipeline students fall away and stop formal schooling, either to go into the work force as beginning SMEs or to pursue other career plans. The final significant reduction in the SME pipeline takes place at this time.[14]

Advantages. Intervention programs focused on these areas of reduction could result in keeping more of the committed group of SME pipeline youth interested in SME careers. For instance, if colleges and universities were to initiate programs for saving some of the students dropped during the first 2 years, a near-immediate result would be seen at the end of the pipeline. The closer to the end of the pipeline that attrition is reduced, the more immediate the impact on SME supply and the smaller the expenditure of time and energy.

Disadvantages. There are at least two disadvantages to this approach. First, it may be difficult to implement such programs at this time, since they would require some funding—probably federal funding. But many different types of intervention programs are already in existence to encourage youth, especially women and minorities, to study science and math. These would need to be refocused and expanded to implement this option.

[14]It could be argued that those going directly into the SME work force are not "lost." But given the challenges of the 21st century, it is clear that we will increasingly need SMEs with education beyond the college level.

Another disadvantage, or at least problem, is that such programs may be perceived (probably mostly by academicians) as lowering the quality of the graduate SME population by keeping in the pipeline some students who would otherwise drop out for (good) academic reasons. Some science and engineering departments apparently take great pride in the number of their students who fail to successfully complete key courses in lower division SME sequences, or who may change to other majors.[15] "There seems to be an informal competition on many campuses to see which science classes have the lowest mean grade-point averages. Any organization or enterprise that loses half or more of its potential clients may be in trouble."[16] We believe that, since the screening processes and admission standards are so rigorous, there exists the opportunity to save some of these students without curtailing quality.

Option 4. *Establish a national SME promotional program to urge improved attitudes toward, and public support for, technical excellence in our country.*

We see conflicting attitudes about technical education and excellence. The effect of the National Education Goals for the year 2000, and of required increases in Carnegie units for high-school graduates, both of which call for more math and science education for youth, is being offset by reductions in school support for advanced placement courses and gifted and talented programs, as well as by the increased efforts to "mainstream" students of lesser capability. These latter trends may result in reducing expectations and in teaching down to all students. In addition, there remains a widespread tendency, especially among their peers, to consider technically educated, unusually bright youngsters as being "nerds" or "geeks."

There are many opportunities for recognition of youth who are great athletes, but relatively few for those who excel in technically based subjects. Some perceptive critics of our society see a disturbing trend toward the "dumbing of America," a tendency to forge a system in which academic excellence is not rewarded and efforts are made to create a noncompetitive environment to the point where both standards and opportunities are lowered for all.

Advantages. It should be a national goal to encourage those students who want to study the most rigorous curricula and excel in these disciplines to do so. The National Education Goals are focused on elementary and secondary education. Our proposed SME promotional program would build on that effort. It could structurally be a partnership of industry, academia, and government to encourage excellence in technical education; foster implementation of a voucher system (if necessary); support magnet schools and special science and mathematics schools (like Thomas Jefferson High School in Fairfax County, Virginia); develop intern-

---

[15]As reported by Kenneth C. Green in "A Profile of Undergraduates in the Sciences," *American Scientist*, Volume 77, September–October 1989, pp. 475–480.

[16]Ibid, p. 478.

ships for bright youngsters; encourage work-study programs in high schools, colleges, and universities; and pursue similar innovative programs. There is a chance for a creative partnership of those institutions that have the most to gain from a supportive program and the most to lose from the dumbing of America. It might be worth the attempt.

Disadvantages. This option would be costly, although some of its costs could be defrayed by sources outside government. Widespread support for this program might also be difficult to obtain. To work effectively, this effort would require a concreteness and specificity that in turn would call for much debate, compromise, and consensus. Without these important but difficult characteristics, exercising this option might amount to cheerleading.

The four alternatives offered—do nothing, provide new public incentives, stem losses from the pipeline, and mount a promotional campaign—are not new. They are strategies that have been tried at various times in the past. At this point, however, it seems unreasonable to expect the increased public funding required for a broad SME incentives program. And to do nothing is to abandon any hope for change, at least in the near term. That leaves options 3 and 4. Taken together, they might just have enough impact to make a difference. Surely we should step up our efforts to retain in the SME educational pipeline more of those who are already there. It is irrational to erect barriers that discourage bright, properly educated youth from pursuing SME careers. In addition, a frank public campaign underlining the very real advantages of SME careers may attract greater numbers of capable youth into the SME pipeline. We urge educators, public policymakers, and leaders in the science and engineering fields to attack this important challenge now.

REPORT DOCUMENTATION PAGE

Form Approved OPM No.0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	Oct 96	Final

4. TITLE AND SUBTITLE

American Youth, Science, and Engineering in the New Century

5. FUNDING NUMBERS

C DASW01-95-C-0019

PE 0902198D

6. AUTHOR(S)

Dayton S. Pickett, David A. Smith

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Logistics Management Institute
2000 Corporate Ridge
McLean, VA 22102-7805

8. PERFORMING ORGANIZATION REPORT NUMBER

LMI- IR517N1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Internal Research and Development Report
Logistics Management Institute
2000 Corporate Ridge
McLean, VA 22102-7805

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

A: Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Can America's youth meet the needs of science (including mathematical science) and engineering—or SME—that will arise in the new century? The authors are concerned over a number of gloomy articles and speeches and propose to set the record straight by recounting relevant history since World War II, describing the SME pipeline that supplies professionals for these fields, and discussing supply-and-demand factors that bear on the issue. They attack the notion that American youth are becoming less able academically, while pointing out that lower numbers of college-bound youth are now choosing to pursue SME majors and careers. When all factors are considered, a shortage of SMEs in the 21st century is possible. The problem, they believe, is motivation, not ability. Four options for meeting the challenge are presented, accompanied by a discussion of the advantages and disadvantages of each.

14. SUBJECT TERMS

Science, Engineering, and Mathematics Education for College Bound Youth ; Education in the 21st Century

15. NUMBER OF PAGES

23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL